Q 16: Photonic Quantum Technologies (joint session Q/QI)

Time: Tuesday 11:00–13:00 Location: A320

Q 16.1 Tue 11:00 A320

Fluorescence Excitation of Quantum Dots by Entangled Two-Photon Absorption — •Tobias B. Gäbler[1,2], Patrick Hendra[1,2], Nitish Jain[1], Erik Prenzel[1], and Markus Gräfe[1,2,3] — [1]Fraunhofer Institute of Applied Optics and Precision Engineering IOF, Albert-Einstein-Straße 7, D-07745 Jena, Germany — [2]Friedrich-Schiller-Universität Jena, Abbe Center of Photonics, Max-Wien-Platz 1, D-07745 Jena, Germany — [3]Technische Universität Darmstadt, Institute of Applied Physics, Hochschulstraße 6, D-64289 Darmstadt, Germany

Fluorescence excited by absorption of entangled light becomes a prominent candidate to tackle the challenges in the state-of-the-art two-photon imaging techniques, such as the requirement of bright excitation light and fast photobleaching. However, due to the low brightness of entangled photon pair sources used in most studies, fluorescence measurements were not feasible.

Our work addresses this issue by optimization of several experimental parts. Initially, a setup of an efficient entangled photon pair source based on nonlinear waveguides was assembled. Secondly, quantum dots were used to maximize the absorption cross sections and thus the probability to detect fluorescence photons. Additionally, we performed coherence measurements to observe influences of single-photon effects.

Our measurements of fluorescence demonstrate that obstacles like disruptive single-photon effects or insufficient photon pair rates can be handled. These results represent the next step towards an experimental realization of entangled light fluorescence microscopy.

Q 16.2 Tue 11:15 A320

Nonclassical states of light via high harmonic generation in semiconductors — •René Sondenheimer[1], Ivan Gonoskov[2], Christian Hünecke[2], Daniil Kartashov[3], Ulf Peschel[4], and Stefanie Gräfe[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Strasse 7, 07745 Jena, Germany — [2]Institute of Physical Chemistry, Friedrich Schiller University Jena, Helmholtzweg 4, 07743 Jena, Germany — [3]Institute of Optics and Quantum Electronics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [4]Institute of Solid State Theory and Optics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

I will discuss the generation of higher-order harmonics from a quantum optics perspective via the interaction of a semiconductor with a coherent pump field focusing on the regime where strong-field intraband excitations dominate. While the fundamental mode undergoes intricate but sufficiently mild modifications due to nonlinear interactions, the harmonic modes can be described by coherent displacements depending on the position quadrature component of the driving laser field within our approximations. Similar to high-harmonic generation in atoms, all radiation field modes are entangled, allowing for potential novel protocols for quantum information processing with high photon numbers over a large range of frequencies.

Q 16.3 Tue 11:30 A320

Interfacing a quantum memory based on warm atomic vapour with single photons from a semiconductor quantum dot — •Benjamin Maass[1,2,3], Avijit Barua[3], Norman Vincenz Ewald[2], Leon Messner[1,2,3], Jin-Dong Song[4], Stephan Reitzenstein[3], and Janik Wolters[2,3] — [1]Optische Systeme, Humboldt Universität zu Berlin, Germany — [2]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin, Germany — [3]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [4]Center for Opto-Electronic Materials and Devices, Korea Institute of Science and Technology, Korea

The complexity of modern quantum applications demands for heterogeneous technological solutions. In particular, the excellent controllability and robustness of atomic quantum memories and the effectiveness of single photon generation with solid state emitters can serve as a cornerstone for future applications in quantum optics, e.g. synchronization and buffering of optical networks.

We present prospects of using a warm caesium vapour as storage medium for single photons at the caesium D1 line (894nm). Our quantum memory is based on electromagnetically induced transparency (EIT) in a ladder-type configuration and allows for on-demand storage and retrieval of few-photon light pulses with 20 MHz repetition rate. We achieve 1/e storage times of 20 ns and an end-to-end efficiency of 1%. The high storage bandwidth of the memory and the low read-out noise promise compatibility with single photons from deterministically fabricated quantum light sources based on InGaAs quantum dots.

Q 16.4 Tue 11:45 A320

Room-temperature quantum memory: Interfacing atomic vapours and semiconductor quantum dots — •Esteban Gómez-López[1], Quirin Buchinger[2], Tobias Huber[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, 12489 Berlin — [2]University of Würzburg, 97074 Würzburg

Quantum repeaters are a key element for scalable quantum networks, where quantum memories can substantially increase the efficiency of long-distance communications [1]. Quantum memories based on warm atomic ensembles constitute an attractive platform as they can store high-bandwidth photons [2] up to the second range [3]. Here we show an Electromagnetically Induced Transparency (EIT) quantum memory hosted in warm cesium vapour. Storage of faint coherent light pulses shows high readout efficiency. A measured bandwidth in the order of 200 MHz makes the memory compatible with the Fourier-limited emission of semiconductor Quantum Dots (QD) embedded in micropillar cavities [4]. We also present the first attempts to interface the emission from a QD-micropillar with our quantum memory by fine-tuning the emission wavelength of the emitters to the hyperfine transitions of the Cs D1 line, where the EIT memory takes place. This work sets the base for a hybrid quantum memory for single photons from a semiconductor single-photon source based on warm atomic ensembles. [1] P. van Loock et al., Adv. Quantum Technol. 3, 1900141 (2020). [2] N. Sangouard et al., Rev. Mod. Phys. 83, 33 (2011). [3] O. Katz and O. Firstenberg, Nat. Commun. 9, 2074 (2018). [4] H. Wang et al., Phys. Rev. Lett. 116, 213601 (2016).

Q 16.5 Tue 12:00 A320

Raman control for ultrahigh fidelity spin gates for the generation of large entangled photonic states with group-IV vacancies — •Gregor Pieplow[1], Joseph H. D. Munns[2], Mariano I. Monsalve[1], and Tim Schröder[1,3] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Psi Quantum, 94304 California Palo Alto, USA — [3]Ferdinand-Braun-Institut, 12489 Berlin, Germany

Large photonic entangled states such as multiphoton Greenberger-Horne-Zeilinger (GHZ) states or cluster states (CS) play a crucial role as a resource in two key photonic quantum information applications: measurement-based quantum computing, and one-way quantum repeaters. Here, we focus on theoretically investigating the deterministic generation of photonic resource states by employing a promising class of optically active spin defects in diamond: group-IV color centers. Specifically, we investigate the generation of linear cluster states and GHZ states. Because the generation of a large entangled photonic state comprised of single photons requires many iterations of the same coherent operations on a quantum emitter, they have to be of ultra high fidelity or otherwise the quality of the state degrades exponentially. This work provides a highly detailed investigation of the optical coherent control that facilitates single and two qubit gates, which are used for the deterministic generation of highly entangled states. We also introduce an original GHZ and CS quality measure, which will underline the importance of ultrafast and high fidelity control techniques for creating large time-bin entangled photonic qubit states.

Q 16.6 Tue 12:15 A320

Ideal Single Photon Sources at Telecom Wavelengths — •Jonas Grammel[1], Julian Maisch[2], Simone Luca Portalupi[2], Peter Michler[2], and David Hunger[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Univer- sität Stuttgart

Semiconductor single photon sources are fundamental building blocks for quantum information applications. The current limitations of such quantum dot sources are the emitting wavelength and insufficient collection efficiency in fiber-based implementations. In the project *Telecom Single Photon Sources* we aim to realize high brightness, fiber coupled sources of single and indistinguishable photons at the telecom wavelength for the upcoming realization of fiber-based quantum networks. We employ open cavities realized with fiber-based mirrors, in combination with InGaAs quantum dots emitting in the telecom O-band and C-band. To achieve Fourier-limited photons we utilize the lifetime reduction of the emitters via the Purcell effect. We optimize the mode matching between the cavity mode and the guided fiber mode by introducing a fiber-integrated mode-matching optics that can basically reach near-unity collection efficiency.

Q 16.7 Tue 12:30 A320

Spatially and spectraly indistinguishable single mode photons from domain-engineered crystal — •Baghdasar Baghdasaryan[1,2], Fabian Steinlechner[3,4], and Stephan Fritzsche[1,2,4] — [1]Theoretisch-Physikalisches Institut, Friedrich Schiller University Jena, 07743 Jena, Germany — [2]Helmholtz-Institut Jena, 07743 Jena, Germany — [3]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, 07745 Jena, Germany — [4]Abbe Center of Photonics, Friedrich Schiller University Jena, 07745 Jena, Germany

Pure single-photon sources are currently one of the most important goals of photonic quantum technologies. A heralded single photon from spontaneous parametric down-conversion (SPDC) is a good candidate for a pure single-photon source. However, the photons from SPDC occur in pairs, that are highly correlated in space and frequency. This correlation reduces the purity of the heralded photons. Domain-engineered crystals with a Gaussian nonlinear response have been successfully used to minimize spectral correlations and enhance spectral purity in SPDC. However, a general approach, which minimizes both, spectral and spatial correlations, is still lacking. We go beyond the ansatz of the Gaussian nonlinear response and find a general nonlinear response that maximizes both the spatial and spectral purity of the SPDC emission.

Q 16.8 Tue 12:45 A320

Towards time-multiplexed pseudo-on-demand generation of single-photons in the C-band based on SPDC — •Xavier Barcons Planas[1,2,3], Leon Messner[1,2,3], Helen Chrzanowski[2], and Janik Wolters[2,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Institute of Optical Sensor Systems, German Aerospace Center (DLR), Berlin, Germany — [3]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany

The deterministic generation of single photons is crucial for photonic quantum technology applications. Spontaneous parametric down-conversion (SPDC) is one of the most prominent processes for the generation of single-photons, where a classical pump beam can spontaneously convert into (entangled) pairs of signal and idler photons. Despite significant advantages in the versatility and the possibility of room-temperature operation, photon-pairs are emitted probabilistically because of the spontaneous nature of the process. We present first results of our efforts to overcome this limitation through temporal multiplexing [1]. We herald the presence of the signal photon from a monolithic cavity SPDC source [2] by detecting the corresponding idler, and store the signal in a highly-efficient storage loop [3]. The synchronization of the source with the memory provides a pseudo-on-demand single-photon source.

[1] E. Meyer-Scott *et al.*, Rev. Sci. Instrum. **91**, 041101 (2020).
[2] R. Mottola *et al.*, Opt. Express **28**, 3159 (2020).
[3] T. Pittman *et al.*, Phys. Rev. A **66**, 042303 (2002).